EXPERIMENT 10

MODELING OF SYNCHRONOUS GENERATOR

EQUIPMENT

* 3 Phase Synchronous Generator
* Load Box
* AC Voltmeter
* Variable Resistor
* PMDC Motor as a prime mover
* Variable DC Supply
* DC Voltmeter and Ammeter

INTRODUCTION

SYNCHRONOUS GENERATOR

The **synchronous generator** or alternator is an electrical **machine** that converts the mechanical power from a prime mover into an AC electrical power at a particular voltage and frequency. The **synchronous** motor always runs at a constant speed called **synchronous** speed.

The three quantities must be determined in order to describe the generator model:

1. The relationship between field current and flux (and therefore between the field current IF.

2. The synchronous reactance 𝑋𝑠 and the internal generated voltage 𝐸a.

3. The armature resistance 𝑅a.



* DC Test (To find the Armature resistance)

The purpose of the DC test is to determine Ra. A variable DC voltage source is connected between two stator terminals. The DC source is adjusted to provide approximately rated stator current, and the resistance between the two stator leads is determined from the voltmeter and ammeter readings. Then,

**𝐑dc= 𝐕dc / 𝐈dc**

If the stator is Y-connected, the per phase stator resistance is

**𝐑𝐚 = 𝐑dc / 𝟐**

If the stator is delta-connected, the per phase stator resistance is

**𝐑a = 𝟑 / 𝟐 \* ( dc)**

The circuit diagram for DC Test when the stator is connected in Y-connected is shown in Figure 10.2



* Open Circuit Test (Effect of Field Current on Internal Generated Voltage)

The magnitude of internal generated voltage induced in a given stator is Ea = KФ ω Where K is a constant, Ф 𝑖s a 𝑓lux 𝜔 is rotation speed of rotor. Since flux in the machine depends on the field current through it, the internal generated voltage is a function of the rotor field current. The generator is rotated at the rated speed, all the terminals are disconnected from loads, the field current is set to zero first. Next, the field current is increased in steps and the phase voltage (which is equal to the internal generated voltage EA since the armature current is zero) is measured.



OBJECTIVE

* To find the equivalent circuit of the synchronous generator by finding its parameter.
* To learn how to find out the resistance of armature winding.
* To draw magnetization curve of synchronous generator.
* To perform short circuit test on synchronous generator.

APPLICATION

* **Synchronous generators** are commonly used for variable speed wind turbine **applications**, due to their low rotational **synchronous** speeds that produce the voltage at grid frequency.
* **Synchronous generators** can be an appropriate selection for variable speed operation of wind turbines.
* **Synchronous generator** is one of the most commonly used alternators. In the modern power industry, it is widely used in hydropower, thermal power, etc.
* It is used in the systems wherever stable speed is necessary.
* It is used to preserve the power factor (PF).

PROCEDURE

(A) DC Test:

1. Connect the armature in star connection as shown in Figure 10.2.

2. Make connections according to circuit diagram.

3. Apply Vdc across two phases of armature and note down the current Idc.

4. Calculate armature resistance using formula given above and note down in Table – I. Table – I.

5. Take average.

(B) Open Circuit Test:

1. Make the connection as show in Figure 10.3 carefully.

2. Run the rotor with help of prime mover at rated speed (PMDC).

3. Note down the line voltage at zero excitation. If there exist any voltage, this is due to residual magnetism.

4. Now increase the field excitation step by step and note down the corresponding values of generated voltage in Table – II.

5. Draw a graph between generated voltage and field current.

(C) Short Circuit Test:

1. Make connections as shown in Figure 10.4

2. The generator is rotated at the rated speed.

3. All the terminals are short-circuited through ammeters.

4. The field current is set to zero first. Next, the field current is increased in steps and the Armature current IA Current corresponding to Field Current in Table – III. is measured as the field current is increased. Note the Armature

5. Plot the graph between armature current (or line current) and the field current. The graph is a straight line for the short circuit terminals. The magnitude of the armature current is

**𝐈a= 𝐄a / √𝐑𝐚^𝟐 + 𝐗𝐬^2**

IN- LAB WORK QUESTIONS AND ANSWERS

Q1. For what purpose DC Test is used? Write the procedure to perform DC for Synchronous Generator.

**PURPOSE OF DC TEST:**

**Testing** of **synchronous generators** (SGs) is performed to obtain the steady-state performance characteristics and the circuit parameters for dynamic (transients) analysis. The **testing** methods may be divided into standard and research types.

PROCEDURE FOR DC TEST:

1. Connect the armature in star connection as shown in Figure 10.2.

2. Make connections according to circuit diagram.

3. Apply Vdc across two phases of armature and note down the current Idc

4. Calculate armature resistance using formula given above and note down in Table – I. Table – I.

5. Take average.

Q2. If the armature winding of a synchronous generator is connected in wye configuration and Rdc=20 than determine the value of armature resistance.

Ra = Rdc / 2

= 20 / 2

=10 ohm

Q3. Write the procedure to determine Synchronous reactance.

Synchronous reactance method

As described in the armature winding notes, **synchronous reactance** is a combination of armature winding leakage **reactance** and a **reactance** used to represent armature reaction. The **synchronous** machine tests give the induced voltage and the current when armature reaction is greatest, for a range of field current values.

Procedure to determine Synchronous reactance

With the assumption of a linear magnetic circuit, the circuit model (per phase) of a synchronous machine. If Ra is neglected, it then follows that

  
It is immediately seen from Eq. (8.22) that for a given field current under short-circuit condition (/,„ = /so V1= 0),



But Ef = Voc (open-circuit voltage, i.e. Ia = 0 with the same field current). Then with the linearity assumption (8.23)

  
where Voc = open circuit voltage and Isc = short-circuit current on a per phase basis with the same field current.  
Since the magnetization characteristic of the machine is nonlinear, it is necessary to determine the complete open-circuit characteristic (OCC) of the machine (Voc — /f relationship). However, it will soon be shown that it is sufficient to determine one point on the short-circuit characteristic (SCC) of the machine (‘Sc — If relationship) as it is linear in the range of interest (for /sc up to 150% of the rated current).

Q4. What is the effect of changing excitation voltage on the internally generated voltage of synchronous generator?

An increase in field current increases the magnitude of EA but does not affect the real power supplied by the motor. The power supplied by the motor changes only when the shaft load torque changes. Since a change in If does not affect the shaft speed Ns and since the load attached to the shaft is unchanged, the real power is unchanged. Va is also constant, since it is kept constant by the power source supplying the motor.

Q5. Draw the Model of synchronous generator. Properly label all components.

OBSERVATION



(B) Open Circuit Test



(c) Short Circuit Test



ISSUE

Little bit issue faced in finding Ea.

CONCLUSION

Synchronous generators with permanent super magnets are an important alternative to the usage of synchronous machines in the construction of low and medium wind power stations for producing electricity. The advantages of using the synchronous generators with permanent super magnets compared to the usage of synchronous generators with excitation winding are: the lack of rotor losses due to the usage of permanent super magnets, generation of a rotary field of high value by the permanent super magnets, approximately linear running characteristics and higher effectiveness. In perspective, synchronous generators with permanent super magnets may be built, with smaller armature gap, in order to increase the generator power for the same overall dimensions.

POST LAB QUESTIONS

* What is importance of DC test?

**Testing** of **synchronous generators** (SGs) is performed to obtain the steady-state performance characteristics and the circuit parameters for dynamic (transients) analysis. The **testing** methods may be divided into standard and research types.

* How AC resistance differs from DC resistance?

In **direct current** (**DC**), the electric charge (current) only flows in one direction. Electric charge in alternating current (**AC**), on the other hand, changes direction periodically.

**AC resistance** is the **resistance** of the conductor, taking into effect the Skin and proximity effect. The one defined here is called inductive or capacitive reactance or impedance. In **dc**, frequency is Zero so capacitive reactance and inductive reactance are infinity and zero.

3. Explain the graph plotted between If and Vp.

Both are directly proportional to each other if one increases the other increases spontaneously.



4. What is modeling of synchronous machine?

**Modeling of synchronous machines** is essential for power systems analyses. As a generator, it determines the electric characteristics of the power system, especially for the system security, the ability to withstand sudden disturbances such as faults, switching, and load changes.

5. What are the parameters needed for modeling of Synchronous Machine?

The three parameters must be determined in order to describe the generator model:

1. The relationship between field current and flux (and therefore between the field current IF.

2. The synchronous reactance 𝑋𝑠 and the internal generated voltage 𝐸a.

3. The armature resistance 𝑅a.

6. Explain graph of **𝐸a and 𝐼a**

Both are directly proportional to each other if one increases the other increases spontaneously.

